training effects were specific to gastrointestinal function in these patients. A second explanation concerns the training schedule and tools employed by University of Tennessee physicians, where too long an interval between lessons may have led to "forgetting" of learned responses and indicated the necessity for relearning.

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Perceptual Impact of Predictive Compensation for Time Delays in Virtual Environments

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In visually presented virtual environments (VE), measured displacement of the observer's head is used to position and orient the viewed simulation content in head-mounted or other types of video displays. Because of latencies within and between individual VE system hardware and software components, time delay in rendering the visual consequences of input

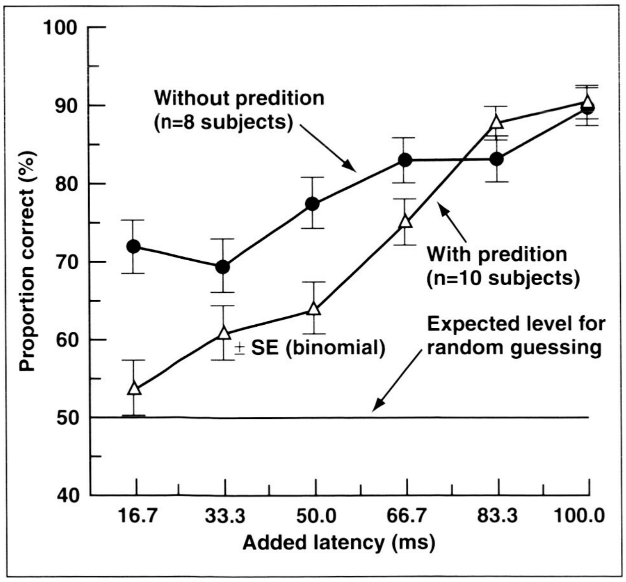

Fig. 1. Generic predictor and uncompensated VE discriminability.

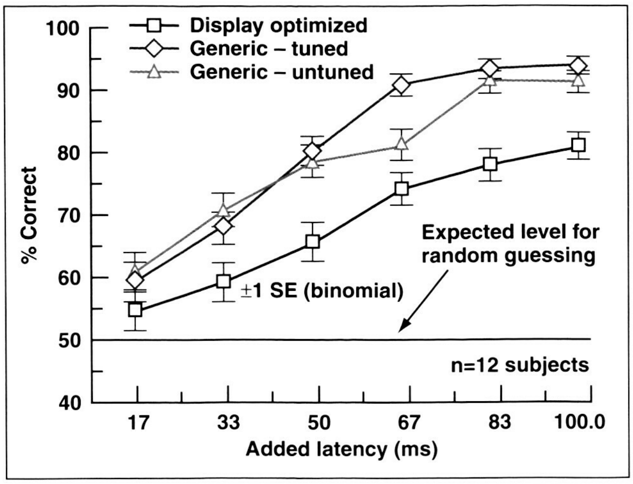

Fig. 2. Discriminability of different predictor designs.

motion is unavoidable. These delays disrupt image stability and, therefore, can disturb the observer's sense of presence and ability to perform useful work in a VE. Predictive compensation software, by extrapolating ahead in time, offers means to mitigate the consequences of VE delays. However, prediction introduces noise and overshoot artifacts into measured human motion that can be as perceptually disruptive as the original uncompensated VE time delay. The immediate objective of this work is to ascertain the perceptual impact of artifacts arising from predictive compensation of VE time delay, and ultimately to use this understanding to guide the design of novel compensation schemes.

A psychophysical method was developed that has allowed the first experimental assessments of the direct perceptual impact of VE motion artifacts induced by different predictive compensation schemes. In the experiments, subjects move their heads in a stereotyped periodic motion while viewing a VE that contains a single, simple, stationary object. Under one condition, the VE operates at its baseline latency. Under the second condition, an artificially added time delay is predictively compensated back to the baseline. In principle then, overshoot, noise, and any other artifacts of imperfect prediction should be the only source of discernible differences between the two. Subjects are asked to judge in a signal-detection paradigm whether the sequentially paired stimuli differ. If the predictive compensation were perfect, subject judgments would be correct at the 50% rate expected for random guessing. The procedure is repeated for different levels of added time delay and different predictor compensator designs.

The protocol was employed in two experiments. In the first experiment, one group of subjects compared the baseline VE latency against the output of a generic predictor that compensated for added delays between 16.7 and 100 milliseconds. For the second group of control subjects, these added delays were not compensated in any way. Results (figure 1) show that the generic predictor, even though not tuned to the specific characteristics of the VE system hardware or software, offers benefit at the smaller latencies because its artifacts are less discriminable than the comparable uncompensated control condition delays.

This observation motivated a second study in which three competing predictor designs were evaluated, this time by a single group of subjects. One compensator was the untuned generic predictor from the first study. The second predictor had the same generic design but was tuned for the specific VE system and subject motion task. The third was optimized to minimize jitter artifacts specifically as rendered in a VE head-mounted display. Results (figure 2) indicate that, although tuning the generic filter had little effect, the display-based optimization made the prediction artifacts less discriminable to the subjects. Offline analysis indicates that the improved perceptual characteristics of the display-based optimization are due to its ability to predict slower volitional motion, while at the same time, unlike the other predictor designs, not magnifying high-frequency jitter.

It is important to note that though predictive compensation can diminish the perceptibility of VE latency, the designs tested have not yet attained the 50% discrimination level of "perceptually perfect" prediction. Moreover, predictor discriminability increased with the addition of time delay, indicative of the challenges in compensating the longer VE delays that will be associated with Internet and satellite communication. The experimental assessment procedure described here, however, will serve to guide the development of new VE predictive compensation schemes and ultimately to validate whether these new designs can predict with the desired level of perceptual transparency.

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Center for Health Applications of Aerospace Related Technologies (CHAART)

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The goal of the Center for Health Applications of Aerospace Related Technologies (CHAART) is to promote the application of remote sensing (RS), geographic information systems (GIS), and related technologies to issues of human health through education, training, and technology transfer. The primary focus of CHAART in FY99 was to support existing, and develop new, collaborations in the application of RS/GIS to studies of human health and surveillance of infectious diseases.

In FY99, CHAART completed another round in the training program for human health investigators. The goals of the training program have been to support human health investigators who integrate RS/GIS into their existing studies, and to facilitate the transfer of RS/GIS technologies to develop sustainable within-country capabilities. With these goals in mind, CHAART participated in several studies of remote sensing of various parasitic and infectious diseases around the world. At the end of FY99, CHAART had received new requests for RS/GIS training from investigators in India, Japan, Korea, Ghana, Ethiopia, Mali, Brazil, and the United Kingdom.

Members of the CHAART staff continued to collaborate with other investigators on the applica-